
Firm: Physical Sciences Inc.

Contract Number: NNX13CC41P

Project Title: Long Life, High Energy Cell Development

Identification and Significance of Innovation: Physical Sciences Inc. (PSI) has combined high voltage operation of commercial cathode materials with its existing silicon composite anode material to build high performance, secondary lithium ion cells. The combination of technologies provides increased cycle life and significantly higher energy density regardless of battery size. Phase I data shows a 30% improvement in the critical fade rate and that additional energy density improvements of >10% can be realized for a total increase in energy density of 25% over equivalent COTS systems. The two keys to the PSI approach are to increase the active material loading and improvement of the cathode electrode formulation to increase the electrode density as well as stabilize the cycling. The novel cathode coating/formulation technique can be applied to increase the cycle life and energy density of all current and future cathode materials.

Technical Objectives and Work Plan: The technical objectives for the program were:

1. Prepare coated cathode electrodes that deliver >98% of the capacity of the uncoated electrodes on C/2 discharge.
2. Demonstrate cathode capacities of >180mAh/g-electrode and 95% capacity retention over 50 cycles.
3. Construct Si/cathode cells at loadings that will enable energy densities of $\geq 265\text{Wh/kg}$ and demonstrate 90% capacity retention over 125 cycles.
4. Produce 1.5Ah cells demonstrating cathode capacities of >180mAh/g-electrode and anode capacity of >1000mAh/g-Si composite material.

The work plan consisted of five tasks: *Task 1.* Cathode Electrode Preparation and Characterization; *Task 2.* Coating Development Application and Refinement; *Task 3.* Lab Cell Construction and Testing; *Task 4.* Ah Cell Construction and Cell Modeling; *Task 5.* Management and Reporting:

Technical Accomplishments: During the Phase I the following was accomplished:

- PSI demonstrated the ability to construct electrodes at loadings of 4 to 5mAh/cm² that deliver the targeted anode (1000mAh/g-SiC) and cathode (180mAh/g-electrode) capacities.
- Successful 1+Ah pouch cell construction with increased loading electrodes. On scale-up, the targeted energy density of 265Wh/kg can be achieved with this system.
- Developed techniques for producing cathode electrodes with capacity >190mAh/g.
- Demonstrated an additional 6% increase in the energy density through the use of this new electrode. Energy densities of >285Wh/kg can be achieved using this electrode.
- Showed a 30% reduction in the critical fade rate of SiC-NCM cells on use of the higher energy density electrode.
- Testing demonstrated over 96% energy retention after 200 cycles at 40% DoD
- Successful PTFE coating of various chemistries (NCM-523, NCM111 and LiCo) without significant changes to the discharge capacity was demonstrated.
- The PTFE coatings were shown to diminish electrode-electrolyte interactions at low voltages, dependent on PTFE coating thickness
- Successful scale-up of the PTFE coating technology for the construction and operation of >1Ah pouch cells.
- Demonstration of improved energy and rate performance of full cells using a higher Si content anode electrode.

NASA Application(s): The proposed cathode technology could be utilized in all NASA battery applications. The cathode coating/formulation approach results in electrodes with higher energy densities and improved cycling performance. In particular the Si-NCM technology could be used in any mission or application that requires low mass, low volume, safe batteries. Applications include EVA suits, landers, rovers, habitats, vehicle power, and power for payloads.

Non-NASA Commercial Application(s): The initial market for the proposed technology is military aerospace applications where space is limited and battery energy density and cycle life is critical. In addition, the technology also would be well suited to powering microdevices, such as remote sensing devices, that would benefit from the increased runtimes and reduced battery size enabled by the increased battery energy density. The technology can be further extended to commercial devices such as hybrid and electric vehicles, cordless power tools, and portable communications such as cell phones and two-way radios.

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